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PHYTOCHEMICAL STUDY AND FORMULATION OF MORINGA OLIFERA CREAMCASTING TECHNIQUE

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ABSTRACT

The "tree of life" or "miracle tree," Moringa oleifera, is regarded as an essential herbal plant because of its many health advantages, both medicinal and non-medical. The plant has historically been used to treat inflammation, cancer, heart illness, liver disease, wounds, and discomfort. It is also used to treat ulcers.

With the intention of assisting future research, this review attempts to gather an analysis of global studies, pharmacological activity, phytochemical, toxicological, and ethnomedical updates of Moringa oleifera, as well as to offer insight into its commercial and phytopharmaceutical uses. Numerous websites and search engines, including Scopus, Pub Med, Science Direct, BMC, Google Scholar, and other scientific databases, provided the scientific data about this plant. Only articles that are accessible in English have been forwarded for evaluation. The hepatoprotective, cardioprotective, and anti-inflammatory properties of the extracts from the different plant sections are validated by the pharmacological research. It was discovered that every portion of the plant contains bioactive components. To date, over a hundred chemicals, comprising alkaloids, flavonoids, anthraquinones, vitamins, glycosides, and terpenes, have been identified from various sections of Moringa oleifera. Furthermore, the plant has been shown to contain unique isolates with strong antioxidant, anticancer, antihypertensive, hepatoprotective, and nutritional properties, such as muramoside A&B and niazimin A&B. This review acknowledges the pharmacological properties of moringa, as well as its traditional and atypical usage, phytopharmaceutical formulations, toxicity profile, clinical investigations, and other applications. Some traditional uses, though, have not yet been thoroughly investigated by science. In order to identify and isolate the active or synergistic components that underlie the plant's medicinal potential, more research is suggested to investigate the plant's mechanistic approach.

Keywords: pharmacological action, phytochemistry, phytopharmaceutical formulation, toxicity, Moringa oleifera, traditional medicinal usage

1. Introduction

Moringa oleifera (M. oleifera), the “miracle tree”, thrives globally in almost all tropical and subtropical regions, but it is believed to be native to Afghanistan, Bangladesh, India, and Pakistan [1]. The Moringa family comprises 13 species (M. oleifera, M. arborea, M. rivae, M. ruspoliana, M. drouhardii, M. hildebrandtii, M. concanensis, M.

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borziana, M. longituba, M. pygmaea, M. ovalifolia, M. peregrina, M. stenopetala), of which M. oleifera has become well known for its use in nutrition, biogas production, fertilizer, etc., [2,3]. Moringa has the unique property of tolerating drought [3]. Studies have shown that M. oleifera is among the cheapest and most reliable alternatives for good nutrition [4]. Nearly all parts of the tree are used for their essential nutrients. M. oleifera leaves have a high content of beta-carotene, minerals, calcium, and potassium [5]. Dried leaves have an oleic acid content of about 70%, which makes them suitable for making moisturizers [6]. The powdered leaves are used to make many beverages, of which "Zija" is the most popular in India [7]. The bark of the tree is considered very useful in the treatment of different disorders such as ulcers [8], toothache [9], and hypertension [10]. Roots, however, are found to have a role in the treatment of toothache [9], helminthiasis [11], and paralysis [12]. The flowers are used to treat ulcers, enlarged spleen, and to produce aphrodisiac substances [2]. The tree is believed to have incredible properties in treating malnutrition in infants and lactating mothers [3]. The present review aims to sum up the updated insight regarding the pharmacological activities, worldwide research analysis, toxicological, phytochemical, and ethnomedicinal properties of M. oleifera.

2. Material Method

2.1. Article Eligibility Criteria

In the framework of searching for study material, the following keywords were used: "Moringa oleifera", "pharmacology M. oleifera", "phytochemistry M. oleifera", "ethnobotanical applications M. oleifera", "toxicology M. oleifera", and other combinations of terms such as biochemical constituents, taxonomic classification, geographical distribution, and plant formulation to search relevant peer-reviewed journals in various scientific databases such as Scopus, PubMed, Springer, Google scholar, and Wiley. Articles available in the English language have only been referred for review. Articles were analyzed by reading the title and abstracts of the articles found, which clearly indicated that they were all relevant.

2.2. Software and Techniques Used

Chemical structures identified in the plants were searched in the Webbook, Chemspider, and PubMed databases, and at the same time, the identified structures were drawn using Chem Draw (version 12.0.2). VOS Viewer software (1.6.18) was used to generate the map of global collaboration between countries. Global country boundaries (GIS layers) were obtained from an open-source web platform (DIVA-GIS) for geographic mapping. Spatial techniques were used with ArcGIS 10.1 to map M. oleifera indigenous and introduced countries and research activities in each country.

3. Worldwide Research and Collaboration

A country-specific research database on M. oleifera was extracted from Scopus, and the data were linked directly to the country shapefile using the "connect field" function in the GIS environment for geospatial mapping. The analyses revealed that scientists from about 15 countries had published more than 100 research papers during the period 2000–2022. Among

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which India was the most prolific country (n = 1083), followed by Nigeria (n = 441), Brazil (n = 383), Egypt (n = 361), China (n = 331), Indonesia (n = 327), Pakistan (n = 281), South Africa (n = 272), Malaysia (n = 260), the United States (n = 214), Saudi Arabia (n = 205), Mexico (n = 163), Thailand (n = 127), and Italy (n = 105), (Figure 1).

International studies on M. oleifera involve the collaboration of scientists from countries such as India, China, Egypt, Saudi Arabia, Cuba, Australia, the United States, Nigeria, and Portugal, which is indicated by circles in the map (Figure 2). The analysis shows that many articles were published in the past decade, indicating the growing interest of researchers in this plant worldwide.

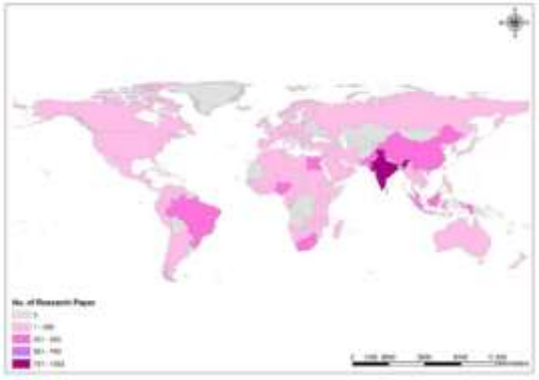

Figure 1. ArcGIS 10.1-based spatial distribution map highlights research papers published on M. oleifera worldwide. A spatial technique was used to generate a map, and GIS layers were obtained from DIVA-GIS, an open-source web platform

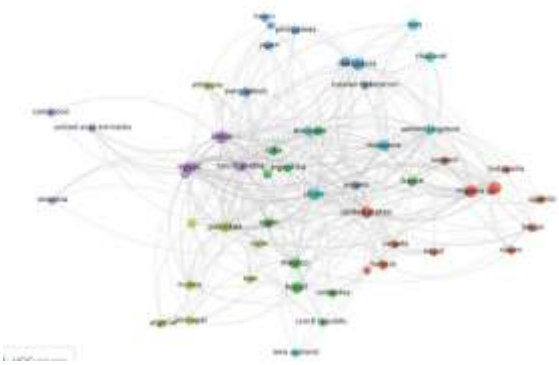

Figure 2. Network visualization of international collaborative research conducted for M. oleifera uing VOS viewer

4. Taxonomical Classification

The plant M. oleifera belongs to the Kingdom: Plantae; Sub kingdom: Tracheobionta; Super division: Spermatophyta; Division: Magnoliophyta; Class: Magnoliopsida; Sub class: Dilleniidae; Order: Capparales; Family: Moringaceae; Genus: Moringa; Species: oleifera.

5. Morphology

The tree grows rapidly in loamy and well-drained sandy soils, preferring a height of 500 m above sea level [1]. Normally, the tree is small to medium in size, the leaves are naturally trifoliate, the flowers are born on an inflorescence 10–25 cm long [14], and the fruits are usually trifoliate and commonly referred to as “pods” [3]. The trunk usually grows straight but is occasionally poorly formed, the branches are usually disorganized, the canopy is umbrella-shaped; the brown seeds have a semi-permeable hull, and each tree has a capacity of about 15,000–25,000 seeds per year [10].

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6. Botanical and Geographical Distribution

M. oleifera is widely distributed worldwide, but its indigenous origin is in India, Arabia and the East Indies. It is common in Asia, Africa, the Caribbean, Latin America, the Pacific Islands, Florida, Madagascar, Central America, Cuba, the Philippines, Ethiopia, and Nigeria [2,15]. The history of the plant explains that M. oleifera was introduced from India to Africa, Southeast Africa, and the Philippines in ancient times [16,17] (Figure 3). It requires tropical and subtropical regions and grows at a temperature of about 25–35 ◦C [1]. M. oleifera is a deciduous type of tree typically grown in tropical and subtropical regions across the globe [18,19]. It grows best in indirect sunlight and without waterlogging, and the soil should be slightly acidic to alkaline. The tree begins to bear fruit at 6 to 8 months of age [18]. Commercially, it is grown in different countries such as Africa, Mexico, Hawaii, and South America, but due to different soil conditions, the nutrient content varies from country to country [3].

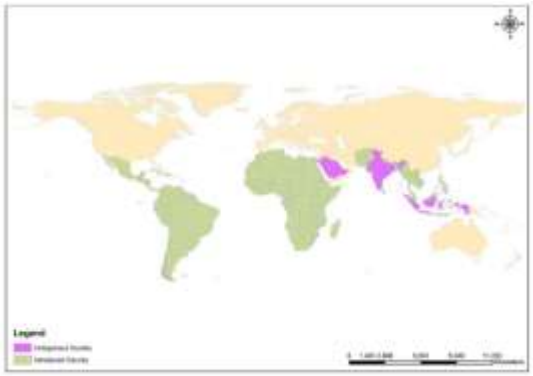

Figure 3. ArcGIS 10.1-based spatial distribution map of Moringa oleifera, the purple color shows the indigenous countries like India, Saudi Arabia, and East indies, whereas the green color shows the introduced countries and regions such as Tropical Asia, Latin America, Africa, Pacific Island, Caribbean Florida, Madagascar, Central America, Cuba, Philippines, Ethiopia, and Nigeria. GIS layers were obtained from DIVA-GIS, an open-source web platform.

7. Ethnomedicinal/Traditional Properties

People worldwide have included M. oleifera in their diet since ancient times because of its vital therapeutic values (Table 1). Various medicines made from the plant are said to have ethnomedicinal properties for curing diseases and have been used for centuries. Approximately every part (leaf, pod, bark, gum, flower, seed, seed oil, and root) of this plant has been used to treat one disease or another [20]. Uses of M. oleifera are observed in pathological alterations such as antihypertensive [10], anti-anxiety [21], anti-diarrheal [22], and as a diuretic [23]. Moringa is also used to treat dysentery [24] and colitis [25]. A poultice made from Moringa leaves is a quick remedy for inflammatory conditions such as glandular inflammation, headache, and bronchitis [9]. The pods treat hepatitis and relieve joint pain [19]. The roots are conventionally used to treat kidney stones [26], liver diseases [27], inflammation [28], ulcers [29], and pain associated with the ear and tooth [30]. The bark of the stem is used to treat wounds and skin infections [31]. Indians use the gum extracted from this plant to treat fever, and it is also used to induce abortions [32]. The seeds of the plant act as a laxative and are used in the treatment of tumors, prostate, and bladder problems [33]. The seeds show promise for the treatment of arthritis

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by altering oxidative stress and reducing inflammation [34]. Preparations from the plant leaves benefit nursing mothers and malnourished infants and improve the general health of the population. The leaves have been useful for patients suffering from insomnia [35] and treating wounds [36]. Moringa is used incredibly extensively in the cosmetic industry nowadays, and in ancient Egyptian history, it was similarly used for preparing dermal ointments [37].

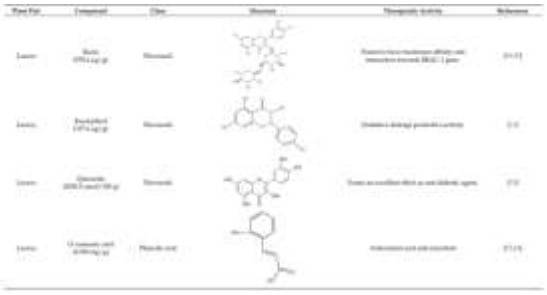
Table 1. Uses of Moringa oleifera listed in Ayurvedic medicinal textbook

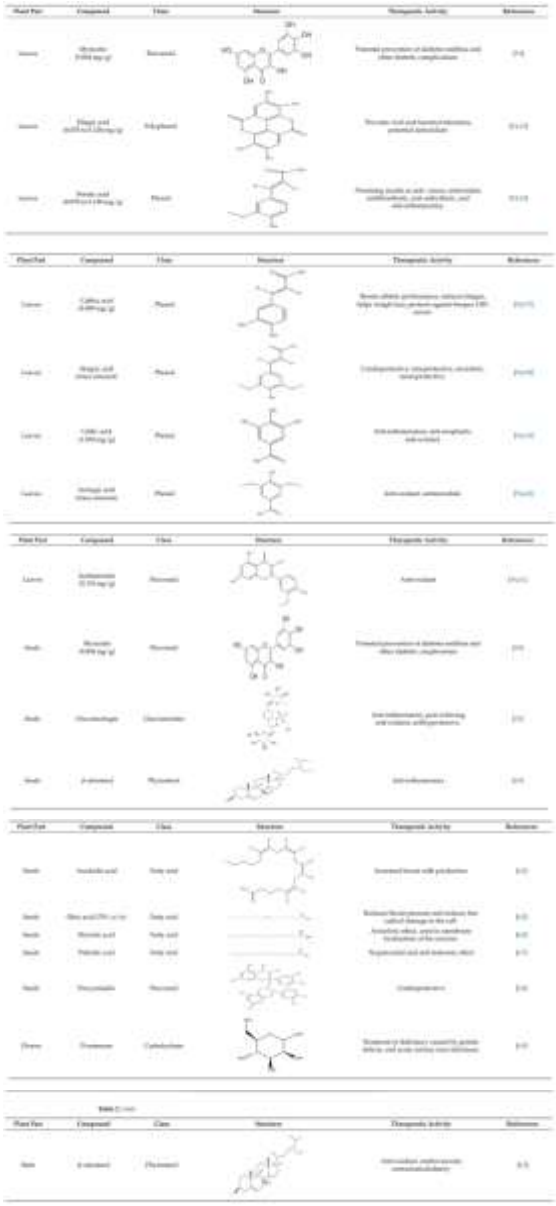
Name of Ayurvedic Text	Form of Plant Used	Treatment	References
Charaka Samhita (1000 BC–4th Cent. AD)	Powder Decoction	Used for treatment of worms and headache, Ascites, edema Hiccough and asthma, deafness, tinnitus in the ear, worm's manifestation.	[38]
Ashtanga Hridaya (7th Cent. AD)	Oil	Ear ache, deafness, and tinnitus in the ear	[39]
Kashyapa Samhita (6–7th Cent AD)	Decoction Oil	Puerperal disorder, sleeplessness Edema	[40]
Sharangadhara Samhita (13 Cent. AD)	Decoction	Conjunctivitis	[41]
Yogaratnakara (17th Cent. A.D.)	Decoction	Enlargement of spleen, worm edema, Ascites, fever, abscess.	[42]

8. Pharmacological Uses

Recent pharmacological studies have revealed that different extracts of M. oleifera exhibit different pharmacological activities, such as antimicrobial [43], antifungal [44], anti-inflammatory [45], antioxidant [46], anticancer [47], fertility [48], wound healing [43], and other pharmacological activities mentioned below (Table 2).

Table 2. Phytoconstituents of Moringa and their relevant therapeutic effects.





8.1. Antimicrobial and Antifungal Activity

M. oleifera ethanolic root extract contains a compound N-benzylethyl thioformate (an aglycone of deoxyniazimincin) responsible for the antimicrobial and antifungal effect toward an extensive array of microbes and fungi [44]. M. oleifera methanolic leaf extract may exert inhibition of urinary tract infections caused by Gram-negative and Gram-positive bacteria such as Klebsiella pneumoniae, Staphylococcus aureus, Escherichia coli, and Staphylococcus saprophyticus.

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The inhibitory effect of extracts from leaves, seeds, and stems of M. oleifera has been specified in various fungal strains such as Aspergillus flavus, Aspergillus terreus, Aspergillus nidulans, Rhizoctonia solani, Aspergillus niger, Aspergillus oryzae, Fusarium solani, Penicillium sclerotigenum, Cladosporium cladosporioides, Trichophyton mentagrophytes, Penicillium species, Pullarium species [44]. M. oleifera seeds have active components 4-(alpha-L-rhamanosyloxy) benzyl isothiocyanates, which are believed to be responsible for their antimicrobial activity [70]. The juice of Moringa leaves also showed potential against human pathogenic bacteria [43]. The methanolic leaf extract has nearly 99% inhibition against Botrytis cinerea (a necrotrophic plant fungus).

8.2. Anti-Inflammatory Activity

A significant anti-inflammatory effect was observed in different parts of M. oleifera (leaf, pods, flowers, and roots). It was observed that the isolated compound (4-[2-o-Acetyl-alpha -l-rahamnoslyloxy) benzyl] thiocynate from Moringa possessed nitric oxide inhibitory activity and was subsequently found to be effective in Raw264.7 cell lines [75]. A compound derived from M. oleifera roots, known as aurnatiamide acetate and 1,3-dibenzylurea, inhibited TNF-α production [76]. Active compounds such as tannins, phenols, alkaloids, flavanoids, carotenoids β-sitosterol, vanillin, and moringin have anti-inflammatory properties [32]. The M. oleifera fruit extract blocked nuclear factor kappa B (NF κB) translocation, and the chloroform extract was found to be cytotoxic at high concentrations (500–1000 µg/mL) [77]. M. oleifera leaves extract was used in mice for treating atopic dermatitis in human keratinocytes and was found to be effective in reducing the expression of mannose receptor mRNA, thymic stromal lymphopoietin, and retinoic acid-related orphan receptor γT in ear tissues (Figure 4).

8.3. Oxidative Stress

The results of M. oleifera were observed in methotrexate-induced mice. The study aimed to look into a probable palliative effect of M. oleifera extract on mice. The mice received the extract one week before administering methotrexate injection, and this treatment was continued for 12 days. The result showed that pretreatment with an extract of M. oleifera on mice poisoned with methotrexate could protect them from oxidative stress [79]. The antioxidant activity of ethanolic extract M. oleifera stems exhibited a protective effect against epidermal oxidative stress injury induced by H2O2 in keratinocytes. The result displayed that the stems showed antioxidant potential, and, therefore, can be used as an excellent and preventive source in animal epidermal oxidative stress injury.

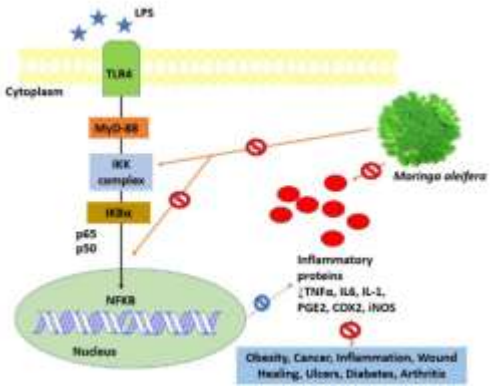

Figure 4. M. oleifera, as an oxidative and inflammatory marker, inhibits IKBα phosphorylation, thereby preventing NFKB (nuclear factor kappa B) inhibition. It prevents the nuclear translocation and

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dimerization of IkBα and NFKB, thereby inhibiting the formation of inflammatory proteins such as TNFα(tumor necrosis factor), COX-2(cyclooxygenase-2), IL6(interleukin -6), and iNos(inducible nitric oxide synthase) and thereby reducing the inflammation and curing other disorders like obesity, arthritis, cancer, diabetes, and ulcer.

8.4 Neuropharmacological Activity

Previous results have proved that leaves extract reestablishes levels of monoamine in the brain and is very helpful in Alzheimer's disease, while the in vitro activity of the ethanolic extract of the leaves showed an anticonvulsant effect on dopamine and norepinephrine levels, locomotor activity, and serotonin (5HT) in the brain in penicillininduced convulsions [98,99]. The methanolic root extract in mice induced by pentobarbital sodium and diazepam has remarkable sedative effects on the CNS by improving sleep duration [35]. The toluene acetate fraction of the methanolic extract proved its potency as a possible nootropic agent [97]. The leaves have shown good anticonvulsant activity in a phenyl tetrazoline and maximal electric shock-induced model using male albino mice [98]. The aqueous extract of the roots blocked the epileptic seizures induced by penicillin in adult albino rats [99]. The ethanolic leaves extract exhibited anxiolytic properties, which were confirmed in behavioral experiments using the actophotometer and the rotarod device, respectively (Figure 5).

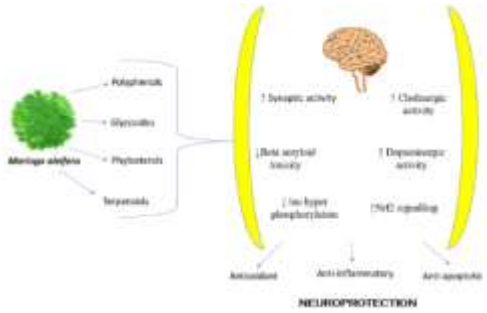

Figure 5. The various phytoconstituents present in M oleifera are responsible for numerous neuroprotective effects. M. oleifera is responsible for upregulating synaptic activity, cholinergic activity, dopaminergic activity, signaling of NrF2 (Nuclear factor erythroid 2-related factor 2), and simultaneously decreasing beta-amyloid toxicity and phosphorylation of tau proteins.

9. Toxicity

Various experimental procedures were conducted to evaluate the toxic potential of the plant. A random selection of female non-pregnant Wistar albino rats was conducted with an oral dose of 2000 mg/kg aqueous methanol solution. Blood samples were collected, and the ALT, AST, and total bilirubin content were determined. The outcome of the study suggested that the lethal dose of the aqueous extract was higher than 2000 mg/kg in female rats.

A similar study was also conducted in Sprague-Dawley rats to evaluate the acute toxic potential of Moringa leaf powder. The experiment also found that oral administration of dried leaves up to 2000 mg/kg had no harmful or lethal effect on the human body [115]. The toxicity of M. oleifera seeds in rats was observed at acute and subacute levels (methanolic extract). Acute toxicity was seen at a dose of 4000 mg/kg, whereas mortality was observed at a dose of 5000 mg/kg. Therefore, in a nut

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shell, it could be summarized that the seed extract could be safe for nutritional use.

The acute toxic study (5000 mg/kg) and subacute (40–1000 mg/kg) results showed no adverse reaction during these studies. However, increased ALT, ALP, and lower creatinine levels were observed. Therefore, it could be concluded that consumption is safe, but intake should not surpass 70 gm/day to prevent cumulative toxicity.

10. Clinical Trials

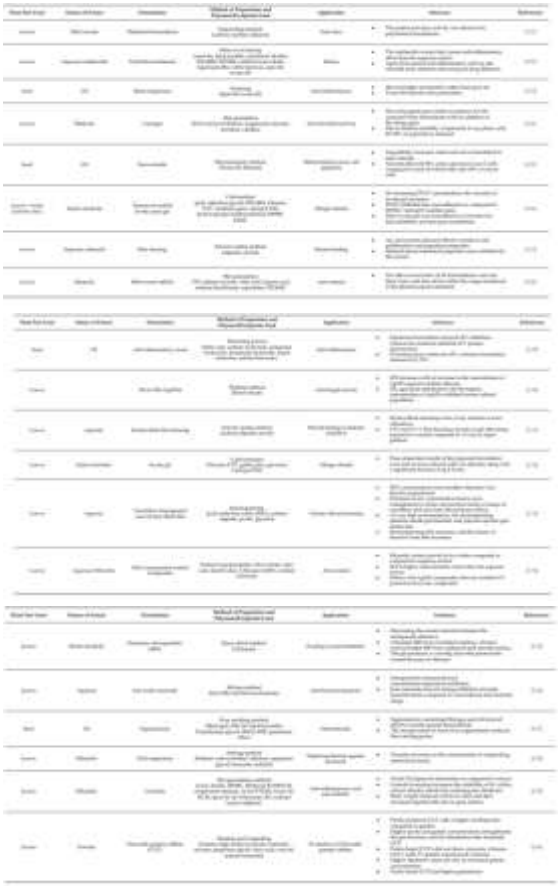
To date, 25 clinical studies have been conducted on M. oleifera, fifteen of which have been completed. Nine of these fifteen studies addressed M. oleifera as part of a diet, while the remaining studies were limited to disease-specific drug interventions. Overall, the studies demonstrated the efficacy of using moringa for conditions such as malnutrition, chronic kidney disease, HIV infection, and reproductive health [119].

A clinical study highlighted the significant role of M. oleifera as an anti-asthmatic agent. In this study, researchers used seed kernels of M. oleifera to treat symptoms of bronchial asthma. Candidates were selected based on inclusion and exclusion criteria, with respiratory parameters and blood samples recorded before and at the end of three weeks of treatment with M. oleifera. The extract was administered to patients in the form of dried powder at a dose of 3 g twice daily for three weeks, and they were instructed to take water with the powder. Symptoms were graded as severe, moderate, and mild on a point table. The results indicate that symptoms and respiratory functions decreased; M. oleifera seeds can effectively treat bronchial asthma [120].

11. Phytopharmaceutical Formulations

Plant extracts have always attracted researchers' attention for producing various pharmaceutical products. This process usually involves the production of medicinal products characterized by two things: first, the production of a stable product, and second, patient compliance. The advantage of Moringa plant extracts is that it appears to be exceedingly safe at the doses and in the amounts commonly utilized for therapeutic efficacy [20]. M. oleifera has been widely accepted in the research area, and scientists have used an array of approaches to develop various formulations. The various phytoformulations prepared using M. oleifera are tabulated below (Table 3).

Table 3. Phytopharmaceutical formulations prepared using M. oleifera extract.



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12. Miscellaneous Uses

A study was performed on M. oleifera using the HPLC-based cyclo condensation method. Astragalin and isothiocyanates were used as markers for standardization of the plant. The conclusive result of the study suggests that the standardized method might be useful for assessing the quality of the development of cosmetic and natural health products.

The extract of M. oleifera leaves was helpful in eliminating the adverse effects of neem oil, which is used in aquaculture as an insecticide to control predators and parasites of fish fry. The researchers concluded that the extract of M. oleifera leaves eliminated the oxidative stress and toxicity caused by neem oil.

The lower yield of okra (Abelmoschus esculentus) was studied. The low production of these crops was due to infestation by pests and insects and poor soil nutrient content. In order to improve production conditions, different chemical pesticides were used, which brought further environmental risks. The use of M. oleifera aqueous leaf extract at different concentrations (1:30 and 1:40) proved beneficial for okra.

The efficacy of M. oleifera leaf and root extract was evaluated as a plant growth regulator and biopesticide in the wheat harvest. The researcher used different concentrations (5, 10, 12.5, 25% w/w, w/v, v/v) of Moringa leaf and root extract at different stages of the wheat plant. Significant plant growth was observed, resulting in increased yield and a decrease in aphid invasion

M. oleifera is rich in macronutrients and micronutrients, vitamins, phytohormones, alkaloids, and flavonoids, which make this plant a multipurpose plant. Recent research has shown that Moringa extract is also helpful in tolerance to abiotic and biotic stress under stressful environmental conditions

The therapeutic effect of bioactive constituents (flavonoids, alkaloids, tannins, isothyocyanin and beta-sitosterol) present in M. oleifera has been reported in chronic diseases such as hyperlipidemia [149], hypertension [150], hepatoprotective [151], anti-cancer [152], Alzheimer's disease [153], Parkinson's disease

Apart from its wide use in preventing and curing various human diseases, Moringa is known for a number of non-medicinal uses, chief among which is its use for poultry, especially in curing viral infections (Newcastle Disease Virus) and other parasitic and bacterial diseases that cause mortality in animals [160]. The plant also serves as an important growth promoter for farmers in the production of tomatoes, peanuts, corn, and wheat in their early vegetative stages [161]. Environmentally friendly biopesticides are produced from this plant, which is cheap and easily available and helps in curing various plant diseases [162]. Studies have shown that the total crop production increased by 20–35% by using M. oleifera leaf extract, which is a good sign for increasing agricultural growth at a minimal cost [163]. The aqueous extract of M. oleifera is a source of various minerals and growth promoters (indole acetic acid, gibberellins, cytokines). It thus can be used as an effective plant biostimulant that

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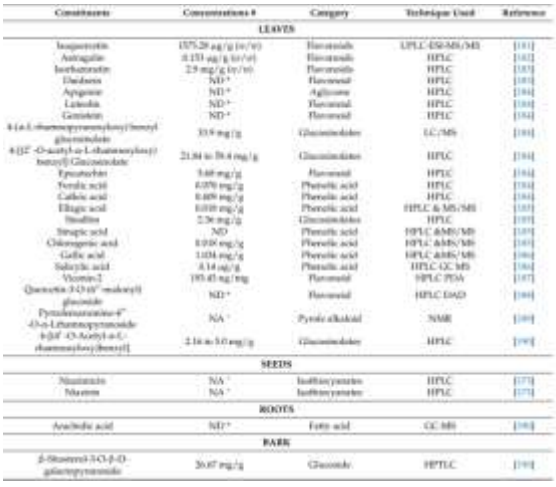
could be a simple alternative to the artificial fertilizers and pesticides available in the market [161]. The methanolic extract of the plant is found to be rich in potassium, calcium, carotenoid, phenols, and zeatin, and when three sprays of this extract are applied on the oilseed rape plant, it is observed that the pods, twigs, height, and number of seeds increase significantly compared to the untreated control group [164]. The ability of the plant to resist drought is due to the plant hormone "zeatin", which is present in large quantities in the methanolic extract, so the plants exposed to such climatic conditions when sprayed with the methanolic extract of Moringa showed improved growth characteristics compared with well-watered plants [165]. The tree is efficient in removing water hardness and is used by African tribes as a cheap source compared to chemical softeners [166]. A study conducted by several groups found that treating river water in African countries with Moringa seeds reduced color and microorganisms by 90% and microorganism (Escherichia coli) levels by up to 95%. Previous reports indicated that a water sample treated with M. oleifera seeds reduced the hardness content of the water by 50–70%, which used to be 80.3 g L−1 CaCO3 [167]. It has also been shown to be an effective solution for treating turbidity, alkalinity, and dissolved organic carbon. It is suggested that Moringa could be, to some extent, an alternative to chemical alum used to remove water turbidity [168]. Moringa is a good source for curing plant diseases and can be a good option for biopesticides [162]. Since various plant pathogens affect the plants, Pythium debaryanum-a pathogen responsible for damping-off disease-can be cured by adding leaves to the soil [169]. Nearly all plant part (fruits, flowers, leaves, seeds, roots) is believed to have different properties that can heal the body spiritually and psychologically [34].

13. Phytochemistry

Almost all parts of M. oleifera and its isolates have been studied for research. Based on the literature collected between 2010 and 2022, more than 90 compounds from the genus Moringa have been identified, many of which have therapeutic potential. The isolates fall into the category of proteins and amino acids [170], phenolic acids [171], carotenoids [172], alkaloids [173], glucosinolates [174], flavonoids [175], sterols [175], terpenes [176], tannins and saponins [177], fatty acids [178], glycosides [179], and polysaccharides [180] (Tables 4 and 5).

Table 4. Phytochemicals present in different plant part extracts of M. oleifera.

Table 5. Select phytoconstituents of M. oleifera isolated through various techniques



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The leaves contain larger amounts of calcium, potassium, proteins, and amino acids such as arginine and histidine

M. oleifera leaves contain a higher concentration of phenolic acids and flavonoids, including cinnamic acid, sinapic acid, syringic acid, gentisic acid, gallic acid, ferulic acid, protocatechuic acid, vanillin, caffeic acid, o- coumaric acid, p-coumaric acid and epicatechin are phenolic acids. In contrast, quercetin, catechin, myricetin, and kaempferol fall under the category of flavonoids having excellent therapeutic activity and are listed above in Table 2.

Fatty acids such as arachidic acid, octacosanoic acid, oleic acid, palmitic acid, stearic acid, linolenic acid, behenic acid, and paullinic acid are found in M. oleifera seeds [178]. Two glycosides, namely niazirin and niazirinin were extracted from the ethanolic extract of M. oleifera [179]. The exudate of the gum contains a large number of poly saccharides such as Dgalactose, L-arabinose, D-xylose, L-rhamnose, D-mannose, and -glucuronic acid [180]. The structure of some of the key phytoconstituents isolated from M. oleifera is shown in Figure 7.

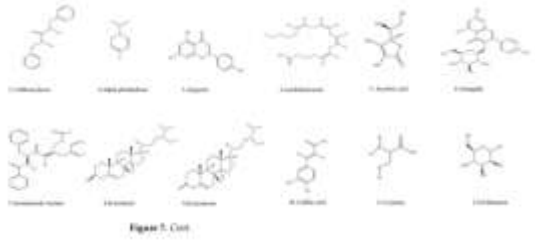

Figure 7. Structure of some key phytoconstituents isolated from M. oleifera

14. Current Status

Moringa is a versatile plant with numerous benefits, and the current status of the plant suggests that it can be used in various pharmacological activities and their related formulations, biomedical applications, livestock, poultry, and fish production, enormously. Extensive research conducted in India, Nigeria, Brazil, and China during 2019–2022 has created a valuable resource for researchers worldwide. After an extensive study of this plant, it was found that M. oleifera has evolved to benefit humans in many ways. A large number of nutrients and phytoconstituents in this plant make it suitable for consumption by humans and animals. Due to its high anti-oxidant properties, it has become a pharmaceutical option for the production of formulations such as wound healing, anti-cancer, and anti-ageing etc. It is suitable not only for human use but also as a fertilizer in various forms extracted from M. oleifera. Besides its benefits, it also has severe toxic and abortifacient effects when taken in large quantities.

15. Conclusions and Future Perspective

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The paper provides an overview of several elements of M. oleifera, such as its global research, phytochemistry, phytopharmaceutical formulations, ethnopharmacology, pharmacology activities, toxicology, and other unspecified criteria. The therapeutic properties of M. oleifera are attributed to the presence of alkaloids, phenolic acid, glycosides, sterols, glucosinolates, flavonoids, terpenes, and fatty acids. Furthermore, M. oleifera has a high content of vitamins, minerals, and carotenoids, all of which contribute to its therapeutic potential and increased popularity as a superfood. Pharmacological research demonstrates that the plant's active ingredients have successfully treated a number of illnesses, including cancer, neuropathic pain, diabetes, hypertension, and obesity. However, there are still a number of phytochemicals whose potential medical uses need to be investigated. Apart from its medicinal application, farmers employ the plant as a reliable biostimulant in their agricultural practices, as it has shown to be an economical substitute. According to a scan of the literature, a lot of preclinical research has been done recently. More clinical research will be needed in the future to examine the plant's potential benefits for treating serious illnesses like AIDS, many malignancies, and coronavirus epidemics. Additionally, more mechanism-based research is suggested to investigate the plant's mechanistic method of identifying and isolating chemicals that are active or synergistic. All things considered, M. oleifera lives up to its moniker as the "Miracle tree" and seems to be a phytopharmaceutical and functional food that, if regularly ingested, may be able to treat a variety of chronic diseases in humans. It may also be utilized by doctors as a safer substitute for other medications to treat a range of illnesses.

Conflicts of Interest: The authors declare that they have no conflict of interest with respect to research, authorship, and/or publication of this article.

References

1. Fuglie, L.J. Producing Food without Pesticides: Local Solutions to Crop Pest Control in West Africa, 1st ed.; Church World Service: Dakar, Senegal, 1998; pp. 1–158.

2. Gandji, K.; Chadare, F.J.; Idohou, R.; Salako, V.K.; Assogbadjo, A.E.; Glèlè, R.L.K. Status and utilisation of Moringa oleifera Lam: A review. Afr. Crop Sci. J. 2018, 26, 137–156. [CrossRef]

3. Chaudhary, K.; Chourasia, S. Nutraceutical properties of Moringa oleifera: A review. EJPMR 2017, 4, 646–655.

4. Gopinath, L.R.; Jeevitha, S.; Gokiladevi, T.; Archaya, S. Isolation and Identification of therapeutic compounds from Moringa oleifera and its antimicrobial activity. IOSR-JPBS 2017, 12, 1–10.

5. Kasolo, J.N.; Bimenya, G.S.; Ojok, L.; Ochieng, J.; Ogwal-Okeng, J.W. Phytochemicals and uses of Moringa oleifera leaves in Ugandan rural communities. J. Med. Plant Res. 2010, 20104, 753–757.

6. Anwar, F.; Ashraf, M.; Bhanger, M.I. Interprovenance variation in the composition of Moringa oleifera oilseeds from pakistan. J. Am. Oil Chem. Soc. 2005, 82, 45–51. [CrossRef]

ISSN PRINT 2319 1775 Online 2320 7876

 Journal Volume 10,Iss 09, 2021

7. Ansari, M.M.; Kumar, S.D. Fortification of Food and Beverages with Phytonutrients. Public Health Nutr. 2012, 2, 241–253.

8. Choudhary, M.K.; Bodakhe, S.H.; Gupta, S.K. Assessment of the antiulcer potential of Moringa oleifera root-bark extract in rats. J. Acupunct. Meridian Stud. 2013, 6, 214–220. [CrossRef] [PubMed]

9. Posmontier, B. The medicinal qualities of Moringa oleifera. Holist. Nurs. Pr. 2011, 25, 80–87. [CrossRef]

10. Aekthammarat, D.; Pannangpetch, P.; Tangsucharit, P. Moringa oleifera leaf extract lowers high blood pressure by alleviating vascular dysfunction and decreasing oxidative stress in L-NAME hypertensive rats. Phytomedicine 2019, 54, 9–16. [CrossRef]

11. Tayo, G.M.; Pone, G.W.; Komtangi, M.C.; Yondo, G.; Ngangout, A.M.; Mbida, M. Anthelminthic Activity of Moringa oleifera Leaf Extracts Evaluated in Vitro on Four Developmental Stages of Haemonchus contortus from Goats. AJPS 2014, 5, 1702–1710. [CrossRef]

12. Hannan, M.A.; Kang, J.Y.; Mohibbullah, M.; Hong, Y.K.; Lee, H.; Choi, J.S.; Choi, I.S.; Moon, I.S. Moringa oleifera with promising neuronal survival and neurite outgrowth promoting potentials. J. Ethnopharmacol. 2014, 152, 142–150. [CrossRef]

13. Paikra, B.K.; Dhongade, H.K.J.; Gidwani, B. Phytochemistry and Pharmacology of Moringa oleifera Lam. J Pharmacopunct. 2017, 20, 194–200.

14. Mallenakuppe, R.; Homabalegowda, H.; Gouri, M.D.; Basavaraju, P.S.; Chandrashekharaiah, U.B. History, Taxonomy and Propagation of Moringa oleifera-A Review. Int. J. Life Sci. 2019, 5, 2322–2327. [CrossRef]

15. Guevara, A.P.; Vargas, C.; Sakurai, H.; Fujiwara, Y.; Hashimoto, K.; Maoka, T.; Kozuka, M.; Ito, Y.; Tokuda, H.; Nishino, H. An antitumor promoter from Moringa oleifera Lam. Mutat. Res. 1999, 440, 181–188. [CrossRef] [PubMed]

16. Vimala, G.; Gricilda Shoba, F. A review on Antiulcer Activity of Few Indian Medicinal Plants. Int. J. Microbiol. 2014, 2014, 519590. [CrossRef]